Spatial analysis of socioeconomic determinants of homicide in Brazil

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Homicide. Residence characteristics. Socioeconomic factors. Spatial Analysis.

Abstract

Objective
To investigate the association between homicide rates and socio-economic variables taking into account the spatial site of the indicators.
Methods
An ecological study was conducted. The dependent variable was the rate of homicides among the male population aged 15 to 49 years, residing in the districts of the State of Pernambuco from 1995 to 1998. The independent variables were an index of the living conditions, per capita family income, Theil inequality index, Gini index, average income of the head of the family, poverty index, rate of illiteracy, and demographic density. The following techniques were used in the analysis: a spatial autocorrelation test determined by the Moran index, multiple linear regression, a spatial regression model (CAR) and a generalized additive model for the detection of spatial trend (LOESS).
Results
The illiteracy and the poverty index explained 24.6% of the total variability of the homicide rates and there was an inverse relationship. Moran´s I statistics indicated spatial autocorrelation between municipalities. The multiple linear regression model best fitted for the purposes of this study was the Conditional Auto Regressive (CAR) model. The latter confirmed the association between the poverty index, illiteracy and homicide rates.
Conclusions
The inverse association observed between socio-economic indicators and homicides may be expressing a process that propitiates improvement in living conditions and that is linked predominantly to conditions that generate violence, such as drug traffic.

INTRODUCTION

As a public health concern, violence has been approached as a social phenomenon of multiple closely coupled determining elements that eventually lie on an unequal and unfair social structure.[1]

Studies in Brazil have shown a relationship between homicide violence and living conditions, highlighting the role of indicators of social inequality.[2-9]

Based on a social inequality approach it has been suggested that relatively high homicide rates derive from individuals' perception of their economic status comparatively to ideal standards of social success. Hence, violence would result from these individuals' frustration of finding themselves in a position of relative poverty while trying to achieve socially legitimate goals.[3]

In addition to social inequalities, some authors

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point out to other determinants that have strongly contributed to homicide growth: expanding bootlegging and firearm possession, illicit drug use, drug trafficking and rivalry over the control of drug-selling points, debt collections and organized groups such as death squads or professional killers. It also should be noted an existing state of non-enforcement of law, slowness of justice, dilapidation, loss of prestige and corruption of public law enforcement institutions as well as downfall of ethical principles.[1,5,10,11]

These factors, among others, are associated in different ways to various circumstances that, even if a single model was likely to fully incorporate this complex issue, generalization would be restricted to the specific scenario under investigation.

Choosing the method to investigate such a complex phenomenon is not a simple undertaking. As there is no all-inclusive explanatory model available on homicides, there have been developed intervention proposals but they are almost always skewed and reflect the sectorial viewpoint of their makers.

Technology advances in geoprocessing have allowed to incorporating the spatial construction of variables and have benefited to investigate this issue as a specific social phenomenon in its socioeconomic, cultural and environmental setting.

Besides enhancing the explanatory ability, such analysis methods allow to identifying population groups, risk areas and providing guidance to further far-reaching interventions.

The purpose of the present study was to investigate the association between socioeconomic variables and homicide rates taking into account the spatial position of indicators.

METHODS

In order to investigate homicides using a quantitative epidemiological approach, an ecological design was set and spatial analyses were carried out to assess the association of explanatory variables at the group level (socio-economic variables).

An ecological study was carried out having the municipalities of the state of Pernambuco as study units. A 1991 mapping from the Federal University of Pernambuco (UFPE) Department of Cartography was used. The municipality of Fernando de Noronha was not included in the study as it is an island with no direct connection with the other municipalities.

Mortality data were collected from the Brazilian Ministry of Health Mortality Information System (SIM)* for the period between 1995 and 1998.

Homicides rates were estimated based on the 1991 Demographic Census population and the 1996 population estimate from the Brazilian Institute of Geography and Statistics (IBGE).[12] In the years between censuses the population was estimated by projection using a geometrical method.

The study dependent variable was homicide rates. The independent variables were as follows: living condition index (LCI), human development index at local level (HDI-L), Gini coefficient, Theil inequality index, per capita family income, average income of the head of the family, poverty index (proportion of those aged 10 years or more categorized by average monthly income of less than one minimum wage), illiteracy rates (proportion of those aged 15 years and more who are not able to read or write) and demographic density. The indicators were selected from the United Nations Development Program (UNDP)[13] and the 1991 Demographic Census.[12]

Multivariate exploratory analysis of independent variables was performed using a correlation matrix to describe the direction and magnitude of associations between indicators.

The spatial autocorrelation was measured by Moran's I index, which ranges from -1 to +1 and provides the autocorrelation strength. The index is positive for direct correlation and negative for inverse correlation. Moran's index assesses whether linked areas have stronger similarity to the studied indicator than that expected in a random distribution.[14]

In order to assess the relationships between dependent and independent variables, multivariate linear regression models were analyzed. It was used the forward approach for selecting variables. The spatial analysis was carried out using the conditional autoregression (CAR) model,[14,15] which provides the spatial dependency of variables. The effects of spatial autocorrelation are associated to the ε error term and the model can be expressed as:

$$Y = X\beta + \varepsilon, \varepsilon = \lambda W\varepsilon + \xi,$$

where $W\varepsilon$ is the error component with spatial effects, λ is the autoregression component and ξ is the

*Data collected from the Brazilian Ministry of Health website, http: www\datasus.gov.br [Sept 2002] error component with constant non-correlated variance. The null hypothesis for non-autocorrelation is that $\lambda=0$, i.e., the error term has no spatial correlation.[15]

The quality of the adjustment of the spatial regression model (CAR), similar to that of the multiple regression model, is assessed through residual analysis using Moran's index.

For spatial regression models the determination coefficient cannot be estimated.

After the spatial dependence has been assessed in the CAR model, the model was adjusted by estimating the spatial trend through additive models. The relationship between the response variable and the independent variable is measured using a non-linear function, usually a non-parametric smoothing method such as LOESS method.[15] In this model, the response variable is described by each one of the socio-economic indicators and the independent variables by the position on the xy coordinates, using the LOESS function as a link:

$$Y = \text{LOESS (latitude)} + \text{LOESS (longitude)}.$$

The LOESS function is a linear regression where the weight of the observations decreases as it deviates from the estimated point. It is thus a local weighted regression.[15]

After trend was excluded, the CAR model was reapplied.

The following software programs were used in the statistical analysis: SPSS-8.0, S-Plus 2000 with Arcview 3.2.

RESULTS

The exploratory analysis of correlations between indicators using a correlation matrix (Table 1) showed that:

- Homicide mortality rates had statistically significant associations with most demographic and living condition indicators, except for the Theil inequality index;
- Among the explanatory variables, the indicators of demographic density, Gini coefficient and Theil index showed weak association with homicide rates (correlation coefficients of 0.25, 0.17 and 0.09 respectively) where as the local human development index (HDI-L), living condition index (LCI), per capita family income and average income of the head of the family showed a positive association of over 0.4. The poverty index and illiteracy rate had also an association of over 4.0, though a negative one, with homicide rates.
- The independent variables were strongly correlated, leading to the exclusion of synthetic indicators such as LCI and HDI-L from the multivariate linear regression model, preventing thus multicollinearity.

In the multivariate linear regression analysis, after applying the forward approach for variable selection, the ultimate model had only two explanatory variables: illiteracy rate and poverty index. The determination coefficient (R^2) found in the adjusted model showed that 24.6% of the total variation of homicides among men aged 15 to 49 years in the municipalities of the state of Pernambuco can be explained by illiteracy rate and poverty index (Table 2).

The residual analysis of the multiple linear regression model showed a residual dispersion suggesting a non-random distribution. Moran's statistical test resulted in a 0.254 spatial residual autocorrelation ($p=0.000$) indicating the need for adjusting variables to a model taking into account a spatial arrangement – the CAR.

The CAR model coefficients were close to those found in the multiple linear regression model and

Table 1 - Correlation matrix of indicators of social inequality and homicide rates (1995-98). State of Pernambuco.

Variables	Homicide rate 1995-98	HDI-L	LCI	Per capita family income	Theil index	Gini coefficient	Head's mean income	Poverty index	Illiteracy rate	Demographic density
Homicide rate 95-98/100,000 inhabit.	1.000*	0.505*	0.473*	0.439*	0.092	0.175*	0.468*	-0.456*	-0.457*	0.255*
HDI-L	0.505*	1.000*	0.953*	0.907*	0.385*	0.498*	0.891*	-0.793*	-0.907*	0.601*
LCI	0.473*	0.953*	1.000*	0.835*	0.290*	0.468*	0.824*	-0.751*	-0.894*	0.538*
Family income per capita	0.439*	0.907*	0.835*	1.000*	0.379*	0.477*	0.956*	-0.848*	-0.707*	0.660*
Theil inequality index	0.092	0.385*	0.290*	0.379*	1.000*	0.600*	0.299*	-0.071	-0.344*	0.206*
Gini coefficient	0.175*	0.498*	0.468*	0.477*	0.600*	1.000*	0.473*	-0.322*	-0.518*	0.289*
Average income of the head of the family	0.468*	0.891*	0.824*	0.956*	0.299*	0.473*	1.000*	-0.805*	-0.709*	0.682*
Poverty index	0.456*	0.793*	0.751*	-0.848*	-0.071	-0.322*	-0.805*	1.000*	0.631*	-0.442*
Illiteracy rate	-0.457*	0.907*	0.894*	-0.707*	-0.344*	-0.518*	-0.709*	0.631*	1.000*	-0.463*
Demographic density	0.255*	0.601*	0.538*	0.660*	0.206*	0.289*	0.682*	-0.442*	-0.463*	1.000

*Significant correlation at p=0.05 (bicaudal)
LCI: Living condition index

Table 2 - Multiple and spatial regression (CAR) models with and with no trend component of homicide rates (1995-98) and the indicators illiteracy rate and poverty index. State of Pernambuco.

Models	Coefficients	Standard error	t	p-value
Multiple regression				
Intercept	401.52	59.86	6.71	0.0000
Illiteracy rate	-1.54	0.47	-3.25	0.0010
Poverty index	-2.70	0.85	-3.20	0.0020
R^2=0.246				
CAR regression				
Intercept	348.59	65.09	5.36	0.0000
Illiteracy rate	-1.93	0.54	-3.56	0.0005
Poverty index	-2.08	0.93	-2.23	0.0269
Rho=0.1545				
CAR regression with no trend				
Intercept	-1.12	3.90	-0.287	0.7740
Illiteracy rate	-1.85	0.53	-3.45	0.0007
Poverty index	-2.23	0.86	-2.60	0.0103

CAR: Conditional auto regressive

both were statistically significant (Table 2). The residual analysis of the spatial model had a non-random variable distribution and Moran's statistical test (-0.1736, p=0.000) showed autocorrelation. The ultimate CAR model, after excluding the spatial trend, showed a marked, though negative or inverse, association between illiteracy, poverty and homicide rates (Table 2).

The risk from homicide rates adjusted by the CAR model, after excluding the spatial trend, showed clustering. Municipalities with higher risk of homicides were concentrated in the metropolitan development area and in other scattered areas such as the semi-desertic rural area and São Francisco backwoods (Figure).

DISCUSSION

Inconsistent results were found in different studies on the association of violence and socio-economic indicators.[16]

Variables such as population size and density, Gini coefficient, poverty and unemployment can be either positively or negatively associated with violence[17] or have no association at all with criminal violence, which indicates both the specificity of violence – violence against people's assets or inflicted to others – and the relationship with other explanatory variables.

In the last two decades an apparently contradictory development has been evidenced: some rich countries where quality of life has been improving (measured by education, health and macroeconomic indicators, women's social condition, expenditures with national security, demographic characteristics, political stability, democratic participation and cultural diversity) have shown increasing homicide rates as well.[18]

Most of all in the 1980s and 1990s, indicators have improved in all development areas[13] of the state of Pernambuco, not only in the living condition index (LCI) but also in other socio-economic indicators such as illiteracy rate among those aged 15 years and more,

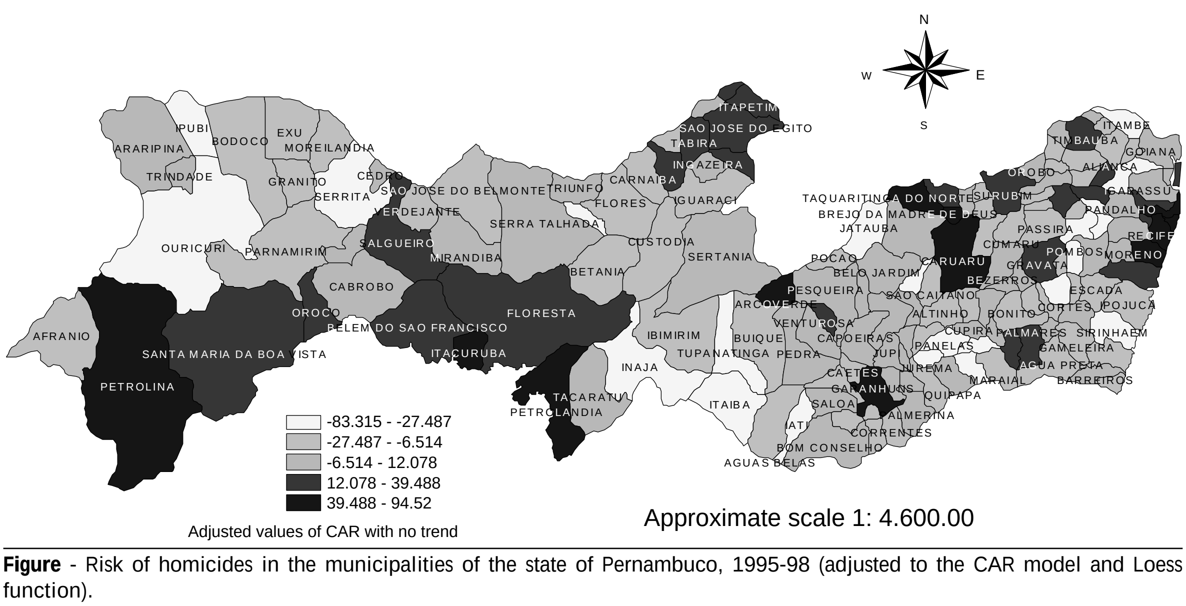

Figure - Risk of homicides in the municipalities of the state of Pernambuco, 1995-98 (adjusted to the CAR model and Loess function).

average schooling of those aged 25 years and more, density of more than two people living in the same household, water supply and adequate sewage system. Nonetheless, in 1991, the average illiteracy rate among those aged 15 years and more was still 32.9% and the poverty index among those aged 10 years and more, estimated by the average monthly income of less than one minimum wage, was 76.8%. These statistics point out to persisting structural violence backing mostly the growth of delinquency, characterized by offenses against people and their properties.

In this scenario, homicide rates have increased in Pernambuco by geographic areas showing an inland movement of violence.[19]

The present study diverges from other previous studies conducted in capitals and states of Brazil in regard to both its methods and results. The study finding of an inverse association between socio-economic indicators and homicides disagrees with most research findings.[2-4,6,9] Concerning the methods, spatial analyses, such as the autoregressive model (CAR) that take into account the spatial position of indicators at the local level, were introduced.[2-4,6,9]

If, on one side, the association found shows the effect of socio-economic factors, on the other side, the inverse association stresses the complexity of the phenomenon studied. It is thus evidenced a much wider set of connections concerning determination, which was partially spotted by local indicators of spatial autocorrelation (LISA), when clusters were identified in two regions: one in an area known as Polígono da Maconha (marijuana polygon) where municipalities are concentrated in three backwoods development areas (São Francisco backwoods, Itaparica, Pajeú/Moxotó) and the other in the metropolitan area.[20] It should be highlighted the role of drug trafficking and urbanization in these areas.

The inverse association found between the improvement of relative poverty and illiteracy and homicide growth can indicate an existing progression toward better living conditions that is mostly linked to circumstances generating violence. It can be hypothesized that the process of producing, distributing and dealing marijuana in the polygon region contributed to the increase of the local population's average income, which has been diminished by low value crops, at the expense of escalating violence. In the metropolitan area of the capital Recife, urbanization and marijuana use and trafficking have produced a fertile ground for violence.

It is assumed that, from the findings of studies mentioned before and the present study, in more industrialized and urbanized Brazilian states, such as São Paulo and Rio de Janeiro, social inequality could result in a diverse impact from that found in Pernambuco. Also, it should be noted that there could have been aggregation bias due to heterogeneity of the size of the study unit (municipality). However, it would be expected a change in the magnitude of the correlation coefficient instead of the inverse association seen in the study.

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